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A transducer for bioacoustic signals

The invention concerns a transducer for bioacoustic signals comprising a transducing element having a front side and a rear side, the front side of which may establish an intimate contact with the surface of a body part, said transducer element being mounted in a housing, which has a surface surrounding the front side of said transducing element, said element and said surrounding surface being in intimate contact with the surface of said body part during use.

Transducers for bioacoustic signals emanating from a body usually belong to two main types applied to an outside surface of the body. One type is a microphone in principle, in which the vibration of a delimited area of skin is picked up as pressure variations in the air surrounding the area of skin, usually the pressure variations in a closed volume delimited by the skin, the microphone diaphragm, and the housing. An enclosed volume is essential to obtain a good low frequency response as well as protection from extraneous airborne noise - one early example is the standard binaural stethoscope in which the bell defines the volume. The second type is an accelerometer in principle, in which a light-weight housing rests against the part of the body and the inertial mass inside provides reference in the generation of signals proportional to the instant acceleration. This type has in itself a good protection against extraneous airborne noises, but the sensitivity decreases and the electrical noise increases very much in the frequency range of interest, unless the inertial mass is increased to a value in which it unavoidably influences the actual measurement. There is hence a need for an improved transducer.

It has been determined that extraneous airborne noise in general enters the transducer by two routes. One is direct airborne influence on the transducing element itself, e.g. a microphone diaphragm. The other is by means of pickup from the skin surrounding the transducer in contact with the body, said acoustical pickup being converted to pressure waves which are re-radiated from the part of the skin surrounded by the housing. It will be noted that this type of noise injection is not avoided by enclosing

the area of skin. There is hence a further need to adress in an improved construction of a transducer for bioacoustic signals.

In US Patent 5, 610,987 a solution is given, which utilises a piezoelectric transflexural diaphragm in direct contact with the skin in the area within the surrounding housing. In this case, the noise signal is coupled to the diaphragm without re-radiation, and the rear of the diaphragm is shielded against extraneous noises by the housing. In order to obtain noise cancellation, this patent also describes that the housing contains an identical but outwards-facing piezoelectric transflexural diaphragm which is only subjected to airborne noise, and that a further identical transducer is placed in contact with the body some distance from the first transducer. Extensive digital signal processing enables a high degree of elimination of the undesired noises. This makes the equipment expensive and causes a need for re-programming if the sensor part is exchanged.

The invention is based on a recognition that if the reverse side of the diaphragm picks up the extraneous airborne noise in a suitable phase relationship, the influence of the airborne noise will be effectively eliminated in a frequency interval of interest. The proper phase relationship is available by just providing access for airborne noise to the rear side of the diaphragm, but further improvement in a frequency interval of interest may be obtained by suitable acoustical loading of the rear side of the diaphragm. Hence, the invention is particular in that the rear side of the transducing element is loaded by an acoustical network which is in communication with the surrounding air, said loading creating an extinguishing relationship between airborne noise signals reaching the front and rear sides of the transducing element respectively.

An advantageous embodiment is particular in that the transducing element is a compound diaphragm giving an electrical output when exposed to bending. This may be obtained in the form of what has been termed a piezoelectric transflexural diaphragm, which is in fact a very thin piezoelectric layer, one side of which is usually bonded to a metal diaphragm and which has a metal layer deposited on the other side. This laminate reacts to shear stresses in the piezoelectric layer occuring

when the diaphragm is bent inwards and outwards by generating a voltage difference between the metal diaphragm and the metal deposit.

A further advantageous embodiment is particular in that the acoustical network consists of a cavity and at least one port in the housing. This is in fact an enclosure for the diaphragm with a leak, and by suitably placing the resonant frequency of this cavity volume and port combination, an extension of the frequency response and in particular of the range of noise suppression may be obtained.

A further advantageous embodiment is particular in that the acoustical network consists of a cylindrical conduit having essentially the same diameter as the diaphragm. This corresponds to letting the diaphragm sit in the bottom of a well, which provides a good shielding and mechanical protection of the diaphragm and connections without any risk that the closure of a port will change the frequency response of the transducer.

A further advantageous embodiment is particular in that he acoustical network consists of a generally frusto-conical conduit, in which the small end has essentially the same diameter as the diaphragm. This corresponds to a horn loading of the diaphragm and will provide a better impedance match from the air to the rear side of the diaphragm.

An advantageous embodiment of the invention is particular in that an elastic material capable of transmitting mechanical vibration is provided in sealing relationship between the skin and the diaphragm. While the diaphragm may be made of stainless steel which is generally regarded as inert with respect to skin, there may be cases of nickel allergy, and for this reason and for normal surface protection of the diaphragm it may be desirable to provide the transducer with a layer of an elastomer. The skilled person will be able to select a material which has suitable transmission properties for this application.

A further advantageous embodiment of the invention is particular in that the effective area of the transducing element is between 1/2 and 1/20 of the area of the surrounding surface of the housing. It has been determined that there is an

improvement in performance when the respective areas are held within these proportions. The effect may be related to the area of contact to the skin and the density of the underlying tissue. By effective area is meant the area of the diaphragm that is actually flexing and contributing to the output, i.e. it is usually less than the opening in the surrounding surface.

The invention will be further described with reference to the drawing, in which

Fig. 1 shows a transducer according to prior art placed on the skin of a body,

Fig. 2 shows a transducer according to one embodiment of the invention, and

Fig. 3 shows curves displaying the noise floor of various transducers.

In Fig. 1 is seen a section of a body resting on its back with a transducer T placed against the skin. The transducer shown in Fig. 1a consists of an outer housing 4 comprising an inner housing 3 holding a diaphragm 1 by its rim and creating a surround 5. Furthermore there is a clamping arrangement 6 for the signal lead and its electrostatic shielding. The housing may also hold a pre-amplifier and impedance converter 2, e.g. using a phantom power supply. The diaphragm 1 is a transflexural piezoelectric laminate known per se which gives off a voltage when flexed. One electrode consists of the actual metallic diaphragm, and the other is deposited onto the other side of the thin sheet of piezoelectric material. The diaphragm is mounted flush with or at least in the same plane as the surrounding part of the housing, and the surround 5 has a diameter or width such that airtight contact with the skin ensured. The housing is closed, thereby shielding the rear side of the diaphragm from airborne sound, and for this reason it is close to the prior art.

Fig. 2 shows a diaphragm of the type described above fitted in a housing, but in this case, according to one embodiment of the invention, the housing provides a cavity or air load on the rear side of the diaphragm. The cavity 7 is in communication with the surrounding air by means of a port 8 with well-defined properties. The surface of the diaphragm touching the skin may be protected by a coat or layer of material 9 that

diaphragm touching the skin may be protected by a coat or layer of material (9) that will not influence the pickup by the diaphragm, i.e. it should posses properties similar to the tissue that the diaphragm is touching. This is indicated by the hatching of the slight depression formed in the surround 5 in which the diaphragm is placed.

In Fig. 3 is shown a graph based on a mathematical model of several transducers interacting with a body, which displays the signal-to-noise ratio, or rather the noise floor, with respect to airborne noise. The characteristics of three types of transducer are shown, a diaphragm with a closed cavity for shielding the diaphragm against airborne noise (the traditional solution), a diaphragm which is directly open to airborne noise at its rear side, and a transducer in which the diphragm is loaded by a complex impedance consisting of a cavity and ports. It will be seen that the traditional solution has a relative airborne noise contribution to the output signal which is -4 dB from 10 Hz to ca. 400 Hz. The simple transducer according to the invention displays a noise floor which is -23 dB at 10 Hz, rising to -4 dB at 600 Hz, and the more complex embodiment using a cavity and port provides a noise floor of -15 dB ± 2 dB from 10 Hz to 150 Hz and only rising to - 4 dB at 800 Hz. This means that there is an improvement of 10 dB in suppression of airborne noise in this embodiment in a frequency range which is of high relevance in stethoscopic signals.

PATENT CLAIMS

1. A transducer (T) for bioacoustic signals comprising a transducing element (1) having a front side and a rear side, the front side of which may establish an intimate contact with the surface of a body part, said transducer element (1) being mounted in a housing (3), which has a surface (5) surrounding the front side of said transducing element, said element and said surrounding surface being in intimate contact with the surface of said body part during use, characterised in that the rear side of the transducing element is loaded by an acoustical network (7, 8) which is in communication with the surrounding air, said loading creating an extinguishing relationship between airborne noise signals reaching the front and rear sides of the transducing element respectively.

2. A transducer according to claim 1, characterised in that the transducing element (1) is a compound diaphragm giving an electrical output when exposed to bending.

3. A transducer according to claim 1, characterised in that the acoustical network consists of a cavity (7) and at least one port (8) in the housing.

4. A transducer according to claim 2, characterised in that the acoustical network consists of a cylindrical conduit having essentially the same diameter as the diaphragm.

5. A transducer according to claim 2, characterised in that the acoustical network consists of a generally frusto-conical conduit, in which the small end has essentially the same diameter as the diaphragm.

6. A transducer according to claim 1, characterised in that an elastic material (9) capable of transmitting mechanical vibration is provided in sealing relationship between the skin and the diaphragm.

7. A transducer according to claim 1, characterised in that the effective area of the transducing element (1) is between 1/2 and 1/20 of the area of the surrounding surface (5) of the housing.

ABSTRACT

In well-known electronic stethoscopic transducers the sensitive element is influenced by signals transmitted via the skin, and the rear side is enclosed in a housing to prevent airborne noise from reaching the sensitive element. According to the invention, an improved signal-to-noise ratio is obtained by letting the transducer be a piezoelectric transflexural diaphragm in contact with the skin, the rear side of the diaphragm communicating with the surrounding air, thereby receiving airborne noise which acts to counteract the influence of noise coming from the skin.

(Fig. 2)

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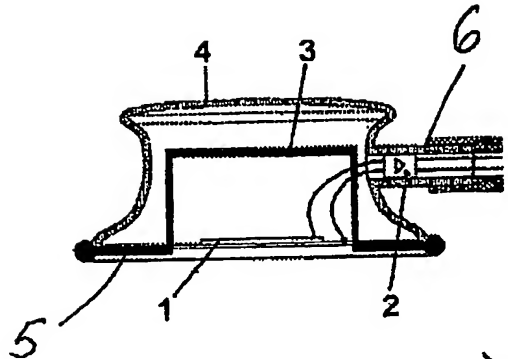

Fig. 1a.

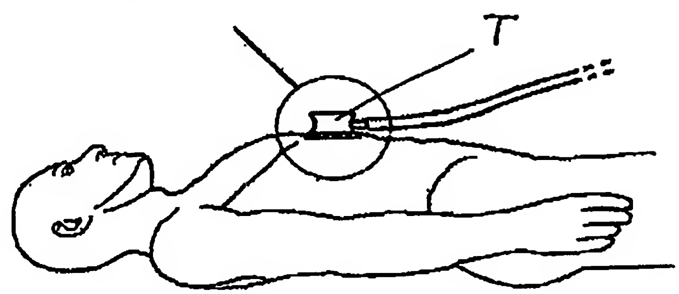

Fig. 1

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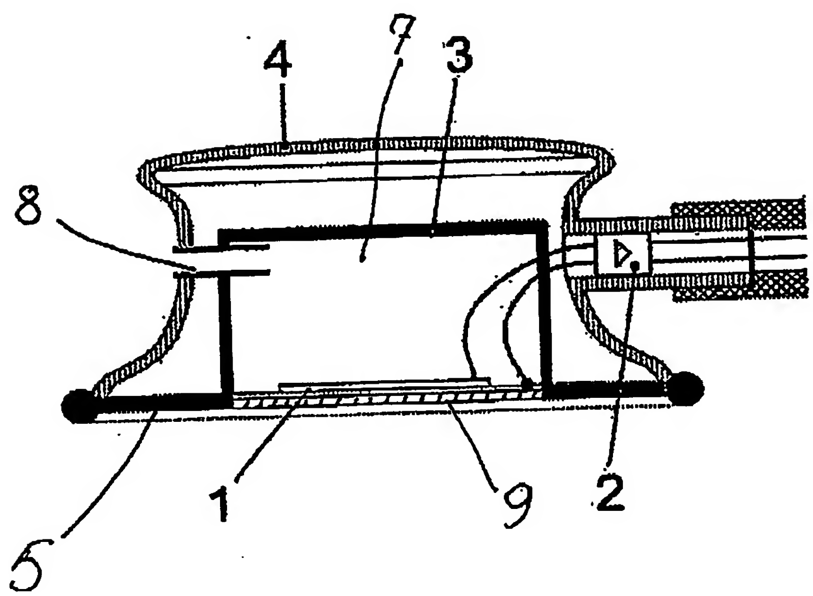

Fig. 2.

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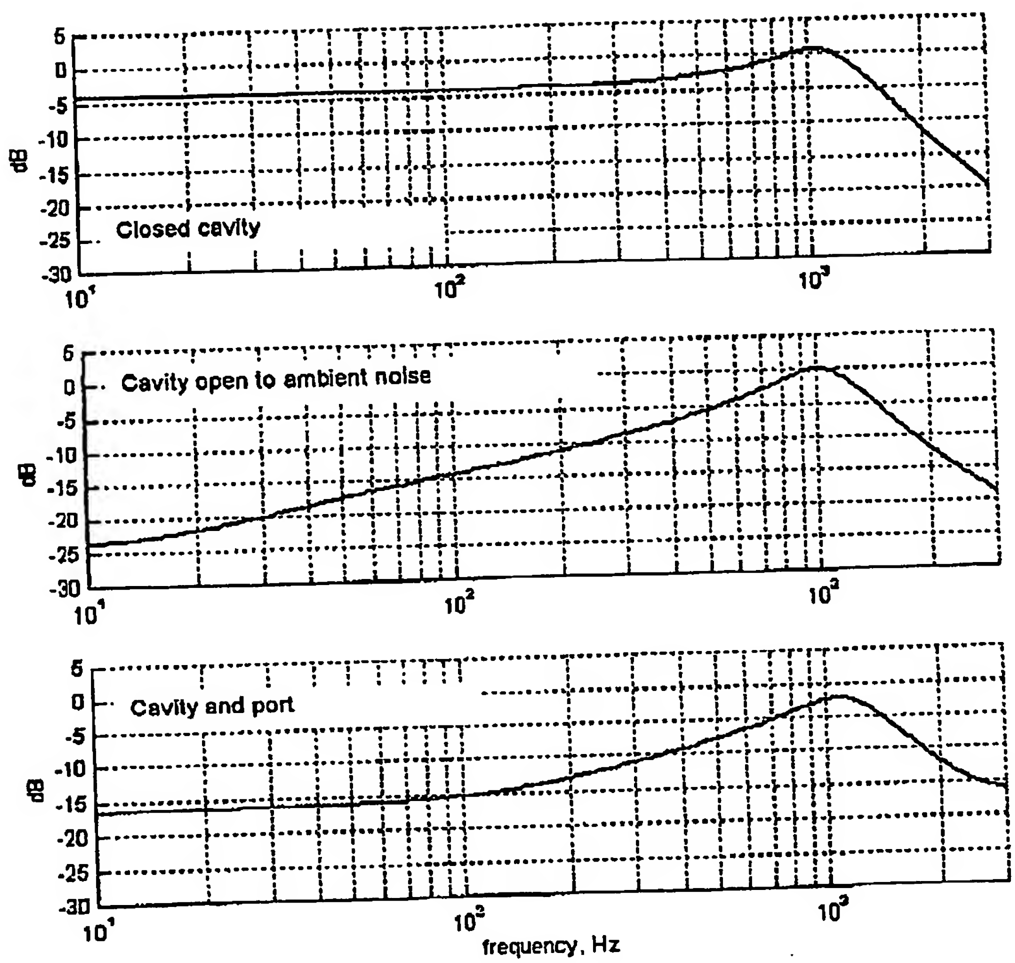
Fig. 3



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